USGS
science for a changing world

Tracking Change Over Time

Earth Images for Education

Contents

Teacher Guide

Tracking Change Over Time: Getting Started

Time Estimate: one class period, up to 1 hour

Suggested grade levels: 5–8

Materials needed: projection system (computer with projector or SMART Board)

Vocabulary: satellite, Landsat, change pair

Next Generation Science Standards

*   Analyzing and Interpreting Data
    *   Analyze and interpret data to determine similarities and differences in findings. (MS-ESS3-2)
*   PS4.B: Electromagnetic Radiation
    *   When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
*   ESS3.B: Natural Hazards
    *   Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)
*   ESS3.C: Human Impacts on Earth Systems
    *   Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
    *   Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4)

National Science Education Standards (NSES)

*   Science in Personal and Social Perspective:
    *   Populations, resources, and environments
    *   Natural hazards

American Association for the Advancement of Science (AAAS) Benchmarks

*   **Physical Setting/Processes that Shape the Earth/ Interdependence of Life; Use of Earth's Resources; Weather and Climate (4C/M7)** Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.

National Geographic Education Standards

*   Standard 14: "Environmental modifications have economic, social, and political implications for most of the world's people. Therefore, the geographically informed person must understand the reasons for and consequences of human modifications of the environment in different parts of the world."

Overview

The Tracking Change Over Time lesson plan includes four parts:

*   Getting Started
*   Understanding Remote Sensing
*   Using MultiSpec to Interpret Satellite Imagery
*   The modules

Once students learn the basics of remote sensing and how to use the MultiSpec software, they can delve deeper into specific
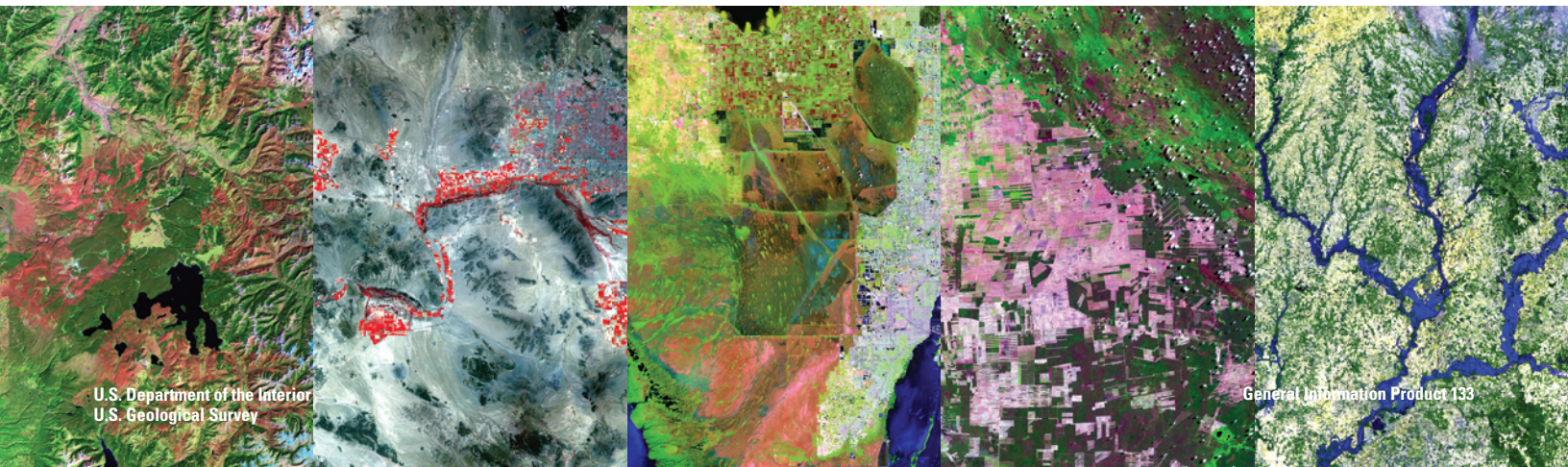
topics with the individual modules. These modules demonstrate the uses of satellite data to track different types of landscape change over time. Students will be able to see how scientists compare images like these to learn more about changes taking place in a region.

The lesson includes two modules: "Urban Area Change—Phoenix, AZ" and "River Flooding." Subsequent modules will address other types of land change including natural hazards, land use change, and climate change. Watch for new module releases and add to this lesson plan!

Getting Started demonstrates the many uses of satellite images, using several Landsat images that will grab your students' attention and clearly show that landscape change can be immediate and dramatic.

Learning Goals

Students will
- Recognize that scientists use satellite imagery to understand how the Earth's surface changes over time.
- Learn that satellite images reveal a multitude of details about the land surface.

Procedures

- National Aeronautics and Space Administration (NASA) Landsat Flyby video
  - You may choose to begin the lesson with this 2-minute video, which highlights Landsat's many benefits to society. (The file is called "NASA_A Landsat Flyby.mp4" and is available at *http://eros.usgs.gov/educational-activities* under "Tracking Change Over Time – Teacher.")
- Earthshots images
  - Show the Earthshots images and explain what these change pairs show. The Earthshots PDF, which has background information, is available at *http://eros.usgs.gov/educational-activities* (New Earthshots trading cards).
  - Use the USGS Earthshots Web site to show even more information about how satellite imagery is used to track change over time: *http://earthshots.usgs.gov/earthshots*.
  - Or print out the images and randomly hand them out to the students. Students can then examine the images and information and exchange with one another until they have viewed all of the image pairs. Allow students to discuss in teams of 2–4. Instruct students to look for lakes, rivers, bays, roads, urban areas, farmlands, forests, mountains, and airports. Students should discuss features that different change pairs may have in common. They could also discuss why each change pair was chosen to be featured on these cards. Students will gain some beginning background information about satellite imagery and what it shows us about the changing landscape.

- The lesson includes several more dramatic Landsat images, which are available at *http://eros.usgs.gov/educational-activities* (each .tif file begins with the filename "Intro_image"). Display each one on the screen. Ask students where in the world each image is from and what features they see. Refer to the Word document "Introduction_Images.doc" for some background information and prompts for each image.
- Discussing various colors and features in these images will enhance learning by providing background for the other activities in this lesson.

Resources

Achieve, Inc., 2015, Next Generation Science Standards: accessed November 20, 2015, at *http://www.nextgenscience.org/next-generation-science-standards*.

American Association for the Advancement of Science (AAAS), 2007, Atlas of Science Literacy—Project 2061: Washington, D.C.

National Aeronautics and Space Administration, 2010, Tour of the electromagnetic spectrum: National Aeronautics and Space Administration, accessed November 20, 2015, at *http://missionscience.nasa.gov/ems*.

National Academies Press, 1996, National Science Education Standards (NSES): Washington, D.C., National Academy Press, accessed November 20, 2015, at *http://www.nap.edu/openbook.php?record_id=4962*.

National Geographic, 2008, National Geographic Xpeditions—Geography standards: U.S. National Geography Standards, accessed November 20, 2015, at *http://education.nationalgeographic.org/standards/national-geography-standards/*.

U.S. Geological Survey, 2015, Land Remote Sensing Program home page: accessed November 20, 2015, at *http://remotesensing.usgs.gov*.

U.S. Geological Survey, 2015, Earthshots—Satellite images of environmental change: Sioux Falls, S.Dak., U.S. Geological Survey Earth Resources Observation and Science Center, accessed November 20, 2015, at *http://earthshots.usgs.gov*.

Please send us your ideas and feedback about this lesson:

U.S. Geological Survey
Earth Resources Observation and
  Science (EROS) Center

47914 252nd Street
Sioux Falls, SD 57198
(800) 252-4547
(605) 594-6511

http://eros.usgs.gov
custserv@usgs.gov

An electronic version of this packet, image files, the MultiSpec software, and related documents are available for download at *http://eros.usgs.gov/educational-activities*

Teacher Guide

Tracking Change Over Time: Understanding Remote Sensing

Time Estimate: 1–2 class periods

Suggested grade levels: 5–8

Materials needed: projection system (computer with projector or SMART Board)

Vocabulary: remote sensing, pixel, resolution, electromagnetic energy, electromagnetic spectrum, infrared, wavelength

Next Generation Science Standards

- Analyzing and Interpreting Data
  - Analyze and interpret data to determine similarities and differences in findings. (MS-ESS3-2)
- PS4.B: Electromagnetic Radiation
  - When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- ESS3.C: Human Impacts on Earth Systems
  - Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
  - Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4)

National Science Education Standards (NSES)

- Science in Personal and Social Perspective:
  - Populations, resources, and environments
  - Natural hazards

American Association for the Advancement of Science (AAAS) Benchmarks

- **Physical Setting/Motion/Waves (4F/M5)** Human eyes respond to only a narrow range of wavelengths of electromagnetic waves-visible light. Differences of wavelength within that range are perceived as differences of color.

National Geographic Education Standards

- Standard 14: "Environmental modifications have economic, social, and political implications for most of the world's people. Therefore, the geographically informed person must understand the reasons for and consequences of human modifications of the environment in different parts of the world."

Overview

Activities lead students to an understanding of what remote sensing means and how researchers use it to study changes to the Earth's surface. Consider the following steps as a sequence, each section building on the previous ones. Nevertheless, these steps are flexible; feel free to adapt the sequence or only cover the steps that are relevant to your class.

Learning Goals

Students will
- Learn how sensors onboard Earth-observing satellites work and how to identify features in a satellite image.
- Learn about the history of the Landsat satellites.
- Investigate how pixels and resolution relate to satellite imagery.
- Use the tools that scientists use to analyze and interpret satellite imagery to investigate changes over time.

1. What is remote sensing?

Remote sensing means observing something from a distance. Satellites in space observe the Earth from a distance and help scientists study large tracts of land and how that land changes over time.
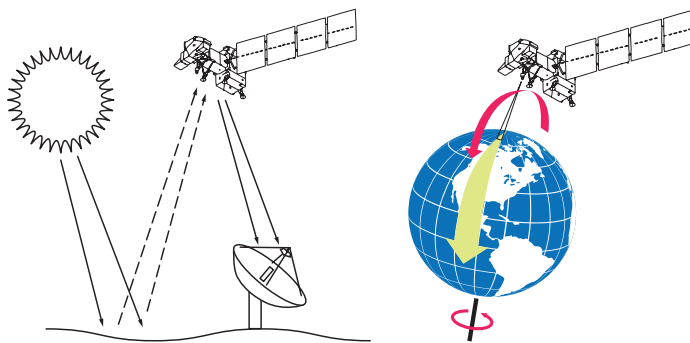
Optical remote sensing satellites use reflected light to detect electromagnetic energy on the Earth's surface. The level of energy is represented by the electromagnetic spectrum, which is the range of energy that comes from the Sun. The light from the Sun that we can see is only a small part of the electromagnetic spectrum and includes the colors of the rainbow. Satellite sensors can detect light that we can't see.

The electromagnetic energy reflects off the Earth's surface and up to the satellite sensor, which collects and records information about that energy. That information is transmitted to a receiving station in the form of data that are processed into an image.

While there are many Earth-observing satellites, these lessons focus on the Landsat series of satellites. The Landsat satellites are in a polar orbit, which, along with the Earth's rotation, allows them to image most of the Earth. As a Landsat satellite revolves around the Earth, its sensor "sees" a certain portion of the Earth's surface. As the satellite orbits the Earth from pole to pole, it appears to move from east to west because of the Earth's rotation. This apparent movement allows the satellite to view a new area with each orbit.

Landsat Uses:

- Geographers look for changes on the Earth's surface that need to be mapped.
- Foresters need information about what type of trees are growing and if they have been affected by disease, fire, or pollution.
- Environmental scientists detect, identify, and follow the movement of pollutants such as oil slicks on the ocean.
- Geologists are interested in finding valuable minerals.
- Farmers monitor how crops are growing and if they have been affected by drought, floods, disease, or pests.
- Ship captains plot the best route through polar ice packs.
- Firefighters send out crews based on information about the size and movement of a forest fire.

2. How do satellite sensors work?

We can only see an object because light bounces off of it and to our eyes. Human eyes can detect only visible light—the colors of the rainbow. Satellite sensors can also detect ultraviolet and infrared light.

The sensors record this information in different portions of the electromagnetic spectrum, which is measured in wavelengths. Landsat satellite sensors detect both visible and infrared light.

When satellite images are made, these "invisible" types of light are assigned visible colors to represent them. That is why some satellite images have strange colors.

Electromagnetic Spectrum

μm = micrometers
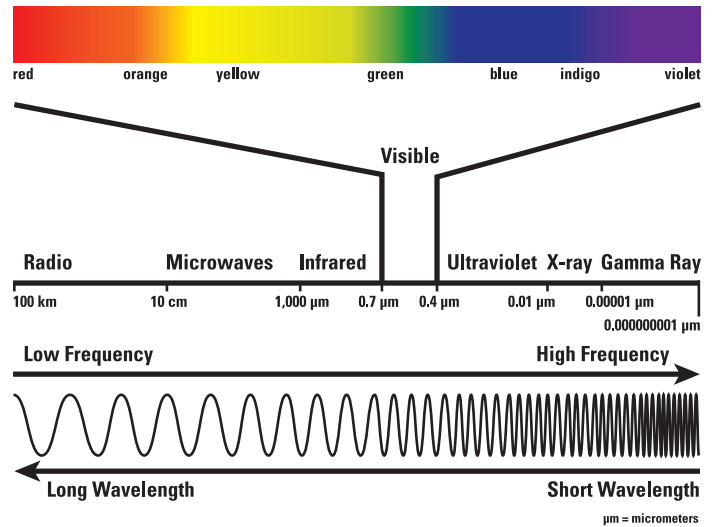
3. What can you see in a satellite image?

In this image of Bellingham, Washington (right), you can see a river (A), urban areas (B), agricultural areas (C), and forest (D). (This image is available at *http://eros.usgs.gov/educational-activities* so you can open it and display with a projector or SMART Board, both with and without labels. The filename is Bellingham.tif.) See if you can find the following features in the image:
- Airport **E**
- River sediment **F**
- Bay **G**
- Lake **H**
- Major streets **I**
- Highway **J**
- Logging clear-cut areas **K**
- Golf course **L**
- Cleared area for power lines **M**

4. The Landsat series

This section contains some of the basic facts about the Landsat series of satellites. Students could read it on their own, or you could highlight certain information.
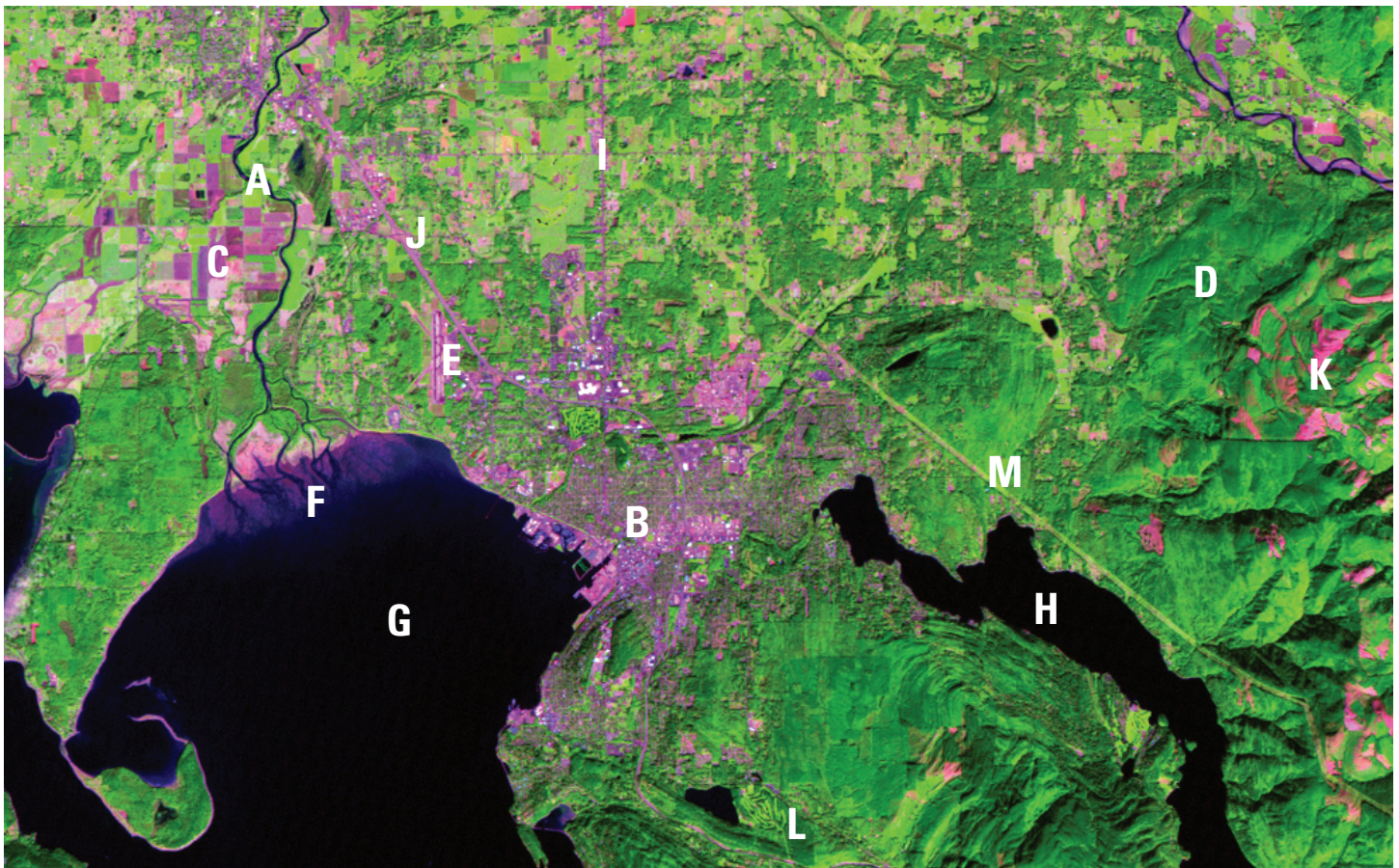
Since 1972, the Landsat series of Earth-observing satellites has been imaging Earth's land areas. Landsat represents the world's longest continuously acquired collection of space-based moderate resolution land remote sensing data. Landsat imagery provides a unique resource for those who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research. Landsat images are also invaluable for emergency response and disaster relief.

The Landsat satellites are launched by NASA at Vandenberg Air Force Base, California. Once the satellite is in orbit, the U.S. Geological Survey (USGS) is responsible for processing and storing (archiving) the satellite data. The USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD, archives and distributes the satellite data.

The two Landsat satellites currently operating are Landsat 7 and Landsat 8. They are in a polar orbit 705 kilometers (438 miles) above the Earth's surface. They complete 1 orbit every 99 minutes, for 14 ½ orbits per day. This means it takes 16 days for each satellite to obtain imagery over the entire globe.

Satellite	Launched	Decommissioned
Landsat 1	July 23, 1972	January 6, 1978
Landsat 2	January 22, 1975	February 25, 1982
Landsat 3	March 5, 1978	March 31, 1983
Landsat 4	July 16, 1982	June 15, 2001
Landsat 5	March 1, 1984	2013
Landsat 6	October 5, 1993	Did not achieve orbit
Landsat 7	April 15, 1999	Still operating
Landsat 8	February 11, 2013	Still operating

5. Identifying Changes over Time

The Landsat satellite image collection is valuable because it shows change over time of the Earth's land surfaces. Look at these two images and find at least five things that have changed between the two time periods. (The images are available at *http://eros.usgs.gov/educational-activities* so you can open them and display with a projector or SMART Board. The filenames are Salt_Lake_City_1985.jpg and Salt_Lake_City_2015.jpg.)

Landsat 5, Salt Lake City, Utah, August 31, 1985.

Landsat 8, Salt Lake City, Utah, September 19, 2015.

- Salt Lake City International Airport, top center, has changed, especially the addition of a runway on the west side.
- Numerous urban areas have expanded, especially to the west and southwest.
- The 2015 image contains several more golf courses than the 1985 image. See if students can locate a few of them.
- In the northeast corner of the images, a new lake appears, the Little Dell Reservoir.
- In the southwest corner of the images is the Bingham Canyon Open Pit Copper Mine, the largest man-made excavation in the world. Some expansion to the mine can be seen on the north side of the pit.
- The large pink and blue shape in the northwest corner of the images is the tailings pond for the copper mine. Tailings are the waste left over from refining the copper. This is a continuously changing landform.
- Ask students what other changes they notice.

6. Types of Change

Brainstorm examples of short-term and long-term changes to the Earth's surface.

Ask students for their ideas and record them on the board. Then ask students the following questions for class discussion:
- Which of these changes are likely to affect your life and why?
- How could these changes be studied? (Visiting the site to see the change, satellite images, reading about the place.)

Short-term changes	Long-term changes
weather	river changing course
forest fire	urban area expanding
crops growing & harvested	deforestation
leaves falling off trees	lake drying up
volcanic eruption	melting glaciers
mining	
building a dam	

- What are the advantages and disadvantages of how these changes can be studied? (Some ideas to address: Visiting the site can be costly and in some cases impossible—the location could be too remote. Visiting the site only lets you see a small area; satellite images allow you to see more area. Satellite images can be expensive; however, Landsat images are freely available to the public online at *http://glovis.usgs.gov/*.)
- How can images from remote sensing satellite sensors help us study landscape changes on the Earth's surface? (People can see large areas and observe how a place changes over months, years, or decades.)

7. What is a pixel?

The resolution of the Landsat satellite data we are using is 30 meters. That means one pixel is equal to a square 30 meters

by 30 meters, which is about the size of a baseball diamond. For example, one Landsat 5 image contains about 35 million pixels—that's about 35 million baseball diamonds!

> Extra hands-on activity: Have the students measure off a 30x30-meter area to show the size of the surface area of one Landsat pixel. For this exercise, the classroom may be too small and you may need to use the gym or the schoolyard. This exercise helps the students directly visualize the size of a Landsat pixel.
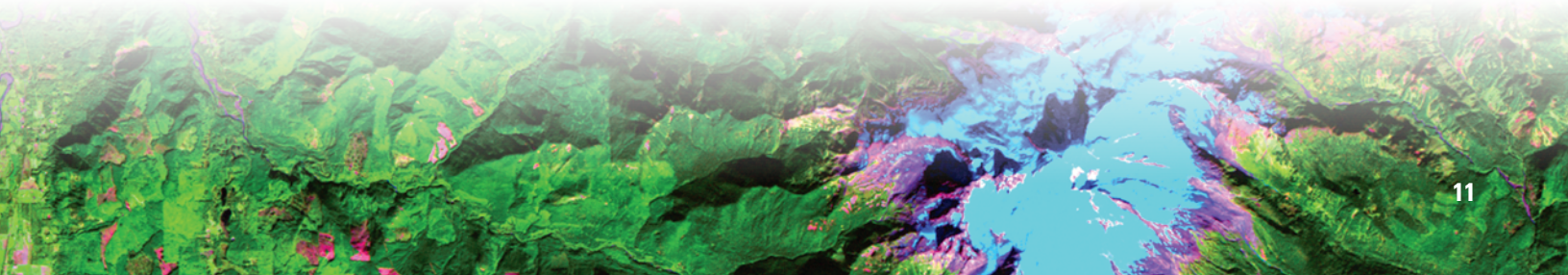
Let's see how a low-resolution image compares to a high-resolution image. On the blank grids, try to create the letter R on the 5x5 grid. (These grids are available at *http://eros.usgs.gov/educational-activities.*) Only whole squares may be used; no diagonals or partial filling allowed. How well does this work? Try a grid with more squares/pixels. Which grid works best for this task, the 5x5, 10x10, or 30x30? Which one produces the best picture?
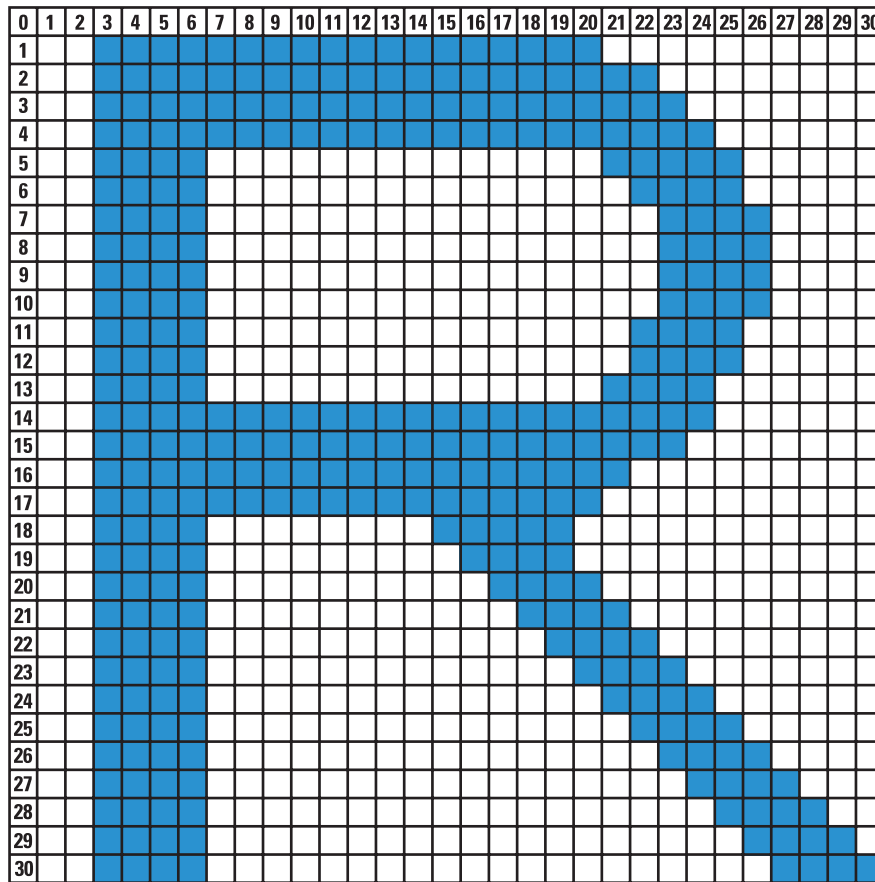
Ask the students to explain why the set of smaller blocks produced a better image. Students should recognize that the smaller the amount of space in a pixel, the sharper the final image will be. But note that the image with small pixels took a lot more work and time to complete. So we need a happy medium—enough detail to be able to observe landscape change but not too much that it is impractical to work with. The 30-meter resolution of Landsat is that happy medium.

The 30-meter resolution of Landsats 7 and 8 works well for observing landscape changes over time. Bigger pixels wouldn't provide enough detail, and smaller pixels would be too much data to be practical to work with. Remote sensing scientists refer to this as moderate resolution. Other Earth-observing satellites, such as NASA's Terra and Aqua satellites, have lower resolutions, up to 1 kilometer. And France's Satellite Pour l'Observation de la Terre (SPOT) has higher resolutions, up to 2.5 meters.

0	1	2	3	4	5
1	▓	▓	▓	▓	
2	▓				▓
3	▓	▓	▓	▓	
4	▓			▓	
5	▓				▓

0	1	2	3	4	5	6	7	8	9	10
1		▓	▓	▓	▓	▓	▓			
2		▓						▓		
3		▓							▓	
4		▓							▓	
5		▓	▓	▓	▓	▓	▓			
6		▓			▓					
7		▓				▓				
8		▓					▓			
9		▓							▓	
10		▓								▓

Resources

Achieve, Inc., 2015, Next Generation Science Standards: accessed November 20, 2015, at *http://www. nextgenscience.org/next-generation-science-standards*.

American Association for the Advancement of Science (AAAS), 2007, Atlas of Science Literacy—Project 2061: Washington, D.C.

Canada Centre for Remote Sensing, 2007, Fundamentals of remote sensing: Natural Resources Canada, accessed November 20, 2015, at *http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9309*.

National Aeronautics and Space Administration, 2010, Tour of the electromagnetic spectrum: National Aeronautics and Space Administration, accessed November 20, 2015, at *http://missionscience.nasa.gov/ems*.

National Aeronautics and Space Administration, 2005, Play Pixel This!: National Aeronautics and Space Administration accessed November 20, 2015, at *http://spaceplace.nasa. gov/pixel-this/en/*.

National Academies Press , 1996, National Science Education Standards (NSES): Washington, D.C., National Academy Press, accessed November 20, 2015, at *http://www.nap.edu/ openbook.php?record_id=4962*.

National Geographic, 2008, National Geographic Xpeditions— Geography standards: U.S. National Geography Standards, accessed November 20, 2015, at *http://education. nationalgeographic.com/standards/national-geography-standards/*.

U.S. Geological Survey, 2012, Landsat—A global land-imaging mission: U.S. Geological Survey Fact Sheet 2012–3072, 4 p., accessed November 20, 2015, at *http://pubs.usgs.gov/ fs/2012/3072/*.

U.S. Geological Survey Earth Resources Observation and Science (EROS) Center, 2015, U.S. Geological Survey EROS home page: accessed November 20, 2015, at *http://eros.usgs.gov*.

U.S. Geological Survey, 2015, Earthshots—Satellite images of environmental change: Sioux Falls, S. Dak., U.S. Geological Survey Earth Resources Observation and Science Center, accessed November 20, 2015, at *http://earthshots.usgs.gov*.

U.S. Geological Survey, 2015, Landsat Missions home page: accessed November 20, 2015, at *http://landsat.usgs.gov*.

U.S. Geological Survey, 2013, Landsat 8: U.S. Geological Survey Fact Sheet 2013–3060, 4 p., accessed November 20, 2015, at *http://pubs.usgs.gov/fs/2013/3060/*.

Tracking Change Over Time: Using MultiSpec to Interpret Satellite Imagery

Time Estimate: 1–2 class periods

Suggested grade levels: 5–8

Materials needed: projection system (computer with projector or SMART Board)

Vocabulary: RGB, band, additive color, subtractive color, false color, grayscale

Overview

This is a combination lesson and user guide for MultiSpec software (2015.2.12 Version), complete with instructions for running and using it.

Learning Goals

Students will
- Learn how the colors red, green, and blue (RGB) are used to create false color images from satellite data.
- Learn what band combinations are commonly used to reveal different details.
- Learn the basics of the MultiSpec software so they can open images, zoom in and out, find a particular latitude/longitude, change band combinations, crop images, and find the area of a selected region.
- Experiment on their own with a sample Landsat image.

MultiSpec Quick Launch

- **Open a file**
  - File > Open Image
- **Change band combinations**
  - Processor > Display Image
  - Change the numbers under "Channels"
- **Zoom**
  - Use the mountain buttons
  - "X1." for 100% size
- **Show latitude-longitude**
  - Window > Show Coordinate View
  - Change units in the drop-down menu at the upper left to "Lat-Long (Decimal)"
- **Crop**
  - Select an area
  - Processor > Reformat > Change Image File Format
  - Save the cropped image, adding ".tif" to the end of the filename
  - Open the new cropped image

1. Basics of RGB

Before we start opening and working with satellite images in MultiSpec, we need to understand more about how satellite sensors record images. All of the colors in a satellite image, similar to images on a television or computer monitor, are made up of a combination of red, green, and blue, or RGB for short.

The satellite sensors that captured the images you are studying record images in grayscale—each pixel is assigned a value of brightness on a scale from 0 to 255. Black is 0, and white is 255, and shades of gray are in between. (Landsat 8 uses values of brightness on a scale from 0 to 4,095!) These grayscale images are assigned the color red, green, or blue, which display

the brightness of each of these colors. When we combine the three images, we get a false color image. With all of the possible combinations of red, green, and blue values, this provides for a display system capable of providing over a million different colors. Try this color slider to see how this works: *http://www. calculatorcat.com/free_calculators/color_slider/rgb_hex_color_ slider.phtml.* The color slider at this URL provides a fairly simple way of showing students how these three colors can be combined.

RGB to Hexidecimal Converter

Red	Green	Blue		Hexdecimal
0	0	0		000000

Color slider

Stop and Check

- What happens when you set all three colors to the same value, such as 150? (you get gray, lighter gray with a higher number)
- What happens when you make all three colors equal to 255? (you get white)
- Try setting two of the colors to 255 and one to 0. In this color system, for example, red and green combine to make yellow. What other combinations do you notice?

Digging Deeper

Students might wonder, "whatever happened to yellow and blue make green?" We might have once learned about *subtractive* color, which is used in art. In subtractive color, the primary colors are yellow, blue, and red, and indeed yellow + blue = green. Satellite sensors, however, use the primary *additive* colors, which are red, green, and blue. The color slider shows the colors that result from combining the primary additive colors.

2. Band Combinations

Landsats 7 and 8 collect several images at once. Each image shows a specific section of the electromagnetic spectrum, called a band. The two tables below show the bands that Landsats 5 and 7, and Landsat 8, collect.

Landsat 5, 7

Band	Portion of Spectrum	Use	Wavelength (micrometers)
1	blue-green	Monitor sediment in water, map coral reefs, and water depth; can also be used to distinguish forest types	0.45–0.52
2	green	Monitor vegetation health, identify human-made structures	0.52–0.60
3	red	Help identify plant species; can help highlight barren lands, urban areas, and street patterns	0.63–0.69
4	near-infrared	Monitor vegetation (leafy plants reflect this band well)	0.76–0.90
5	mid-infrared	Measure vegetation moisture content and soil moisture	1.55–1.75
6	thermal infrared	Measure surface temperature, identify rock types; detect changes in ground temperature caused by moisture variation	10.4–12.5
7	mid-infrared	Monitor moisture content in soil and vegetation; identify minerals	2.08–2.35
8	panchromatic	Used to make images sharper	0.52–0.90

Landsat 8

Band	Portion of Spectrum	Use	Wavelength (micrometers)
1	coastal aerosol	Coastal and aerosol studies	0.43–0.45
2	blue	Monitor sediment in water, distinguishing soil from vegetation and deciduous from coniferous vegetation	0.45–0.51
3	green	Emphasizes peak vegetation	0.53–0.59
4	red	Discriminates vegetation slopes	0.64–0.67
5	near-infrared	Monitor vegetation (leafy plants reflect this band well)	0.85–0.88
6	shortwave infrared 1	Discriminates moisture content of soil and vegetation, can see through thin clouds	1.57–1.65
7	shortwave infrared 2	Discriminates moisture content of soil and vegetation, can see through thin clouds	2.11–2.29
8	panchromatic	Used to make images sharper	0.50–0.68
9	cirrus	Detect cirrus clouds	1.36–1.38
10	thermal infrared 1	Estimates soil moisture	10.60–11.19
11	thermal infrared 2	Estimates soil moisture	11.50–12.51

Landsat 7 and Landsat 8 also use a panchromatic band. This band captures visible and infrared bands at 15-meter resolution and can be used to sharpen images from the other bands. We will not be dealing with the panchromatic band in this lesson.

Three of the bands are combined to form an image, each band assigned red, green, or blue in that order. Different band combinations reveal different details about the surface. In MultiSpec, you will be able to change the band combinations to help identify different features in satellite images.

## Here are some commonly used band combinations and what they reveal:

Landsat 5 Landsat 7	Landsat 8	
3,2,1	4,3,2	this band combination is the closest to natural color; used in urban studies and to detect sediment in water
4,3,2	5,4,3	actively growing vegetation = red urban areas = shades of light blue soils = dark to light brown
7,4,2	7,5,3	actively growing vegetation = bright green sparsely vegetated areas = oranges and browns urban areas = varying shades of magenta dry vegetation = orange barren soil = pink
4,5,1	5,6,2	healthy vegetation = reds, browns, oranges, and yellows soils = greens and browns urban areas = white, light blue, and gray
5,4,3	6,5,4	healthy vegetation = bright green soils = pale lavender

3. Working Your Way around MultiSpec

1. Launch MultiSpec
2. Open the Reno image, which is a Landsat 7 image.
   a. In the File menu, select "Open Image."
   b. In the Open dialogue box, locate the filename Reno.tif and click Open.
   c. The "Set Display Specification for:" box will appear. The name of the image you opened will appear at the top of this box. Leave all of the defaults as they are and click OK.
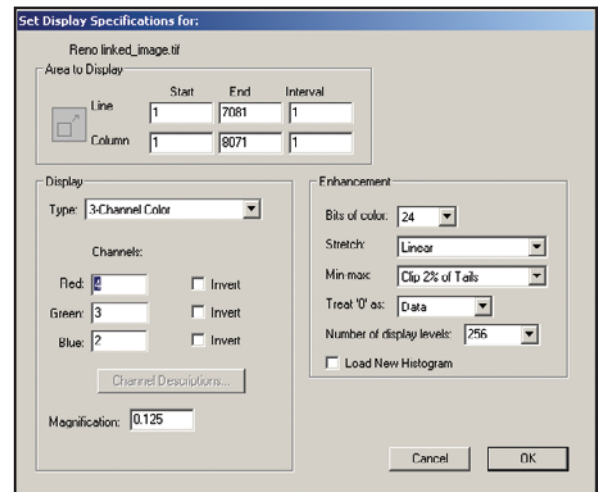

   d. The "Set Histogram Specifications" window appears; leave all of the default settings and click OK.
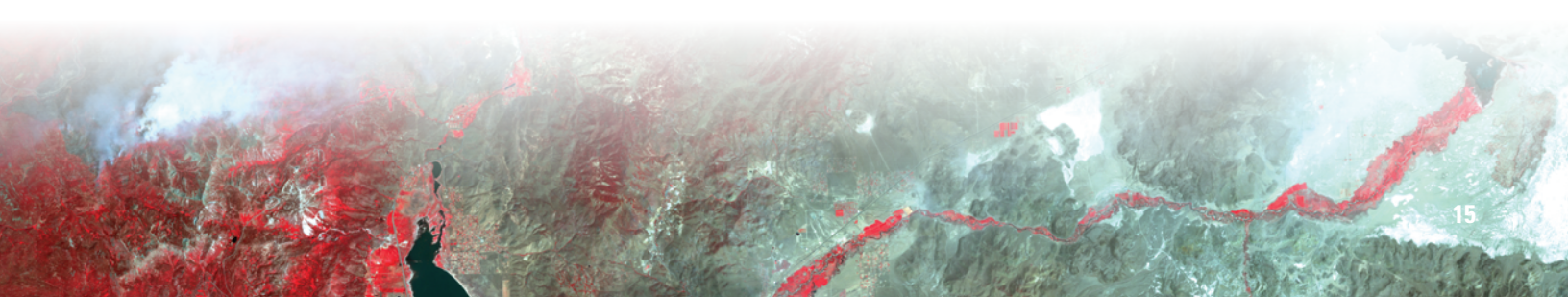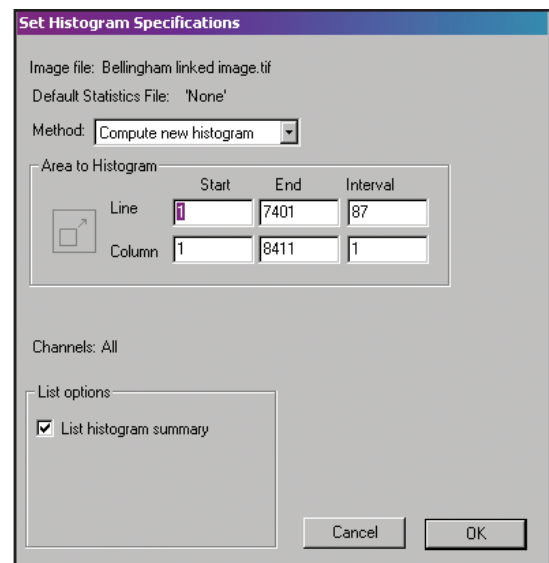
3. How to zoom (magnify the image)
   a. Use the mountain buttons on the Tool Bar to zoom.

    b. The large mountains zoom in, and the small mountains zoom out.
    c. Hold down the Ctrl key to zoom slower.
    d. Click "X1." to make the image 100% in size.
4. How to find a particular latitude-longitude (lat-long)
    a. In the Window menu, select "Show Coordinate View."
   b. In the drop-down menu at the upper left, change the units to "Lat-Long (Decimal)."
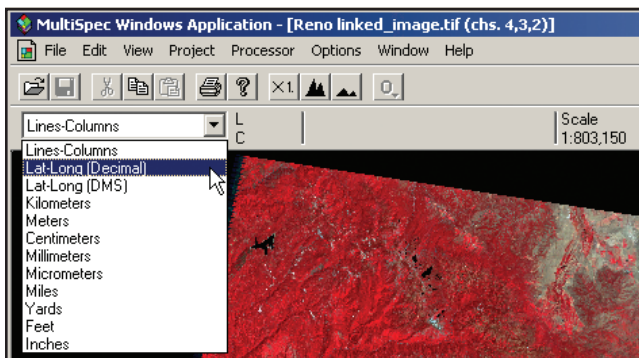
    c. Move the mouse around over the image. Notice how the numbers change.
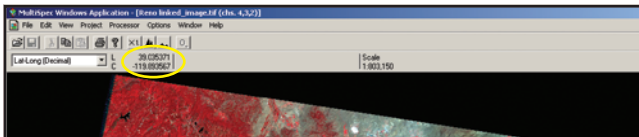
    d. Keep moving the mouse until you are at the latitude-longitude (lat-long) coordinates you want. A forest fire near Reno is at about 39.35° latitude, -120.00° longitude. Click once on the image when you are at these coordinates; you do not have to be too exact.
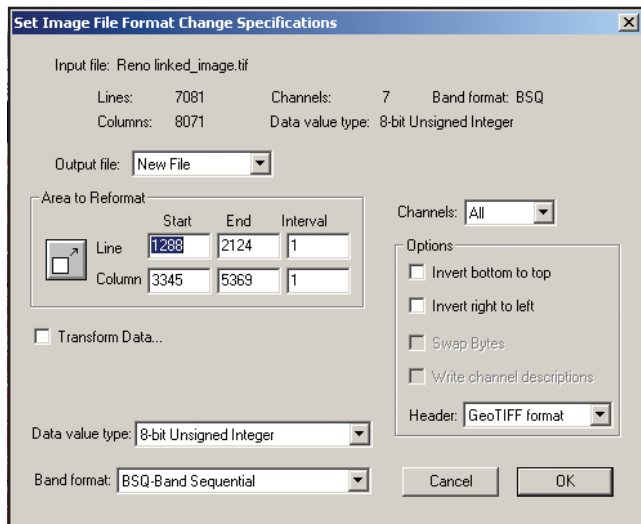   e. Now notice that the lat-long numbers on the right stay locked.
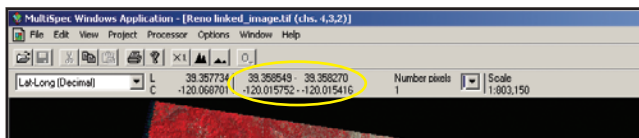
    f. Now you can zoom in on that lat-long and that point will stay in the center until you select another point.
5. How to change band combinations.
    a. In the Processor menu, select "Display Image."
    b. In the "Set Display Specifications for:" dialogue box, change the numbers under "Channels."
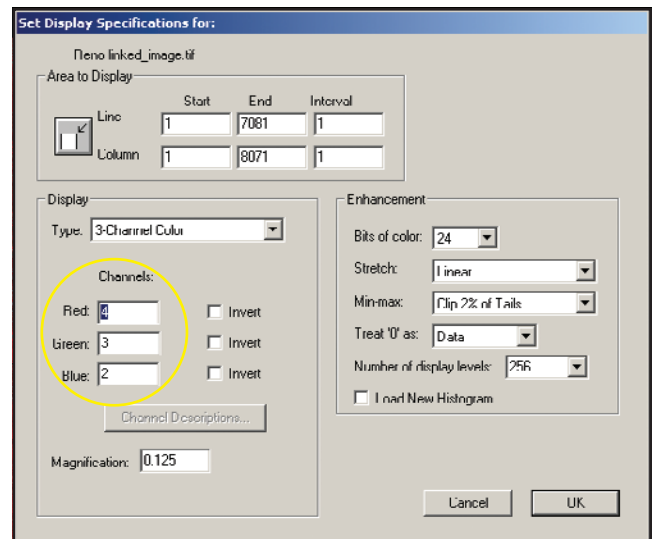

    i. You will only be able to enter numbers 1–7 because there are 7 bands.
    c. Click OK.
6. How to crop.
    a. Click and hold while dragging the mouse to choose a rectangular area to crop. Watch the number under "Number pixels" as you drag; this is the number of pixels that will be in the cropped image. An area less than 3,000,000 pixels should fit on most screens.
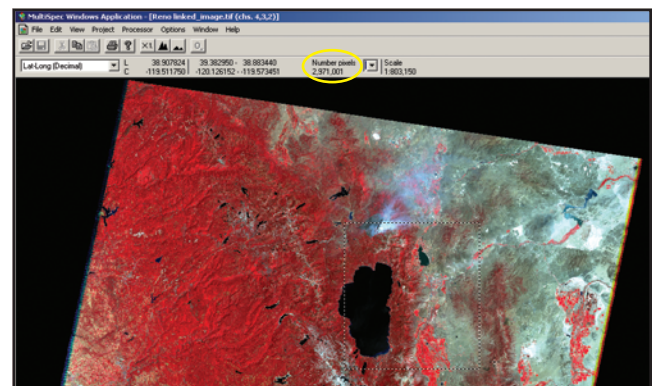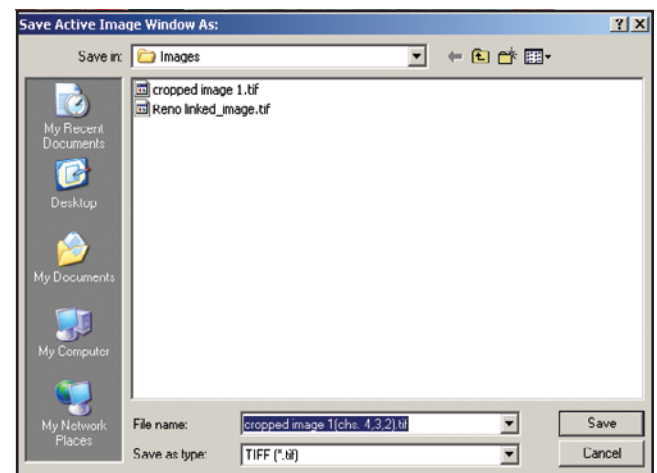
b. In the Processor menu, choose "Reformat" and "Change Image File Format."
c. In the "Set Image File Format Change Specifications" window, leave all of the default settings.

d. Click OK.
e. Choose where to save the new cropped image and give the image a filename, such as "cropped image 1.tif" (make sure the filename has ".tif" at the end). Click Save.
f. Open the image you just cropped (see Step 2).
    i. In the "Set Display Specifications for:" window, you can choose the band combination you want to view, or just click OK.
    ii. The "Set Histogram Specifications" window will appear next; leave all of the default settings and click OK.
g. Now it should be easier to see more detail in your image.
7. How to calculate area.
    a. In the Window menu, select "Show Coordinate View."
    b. Click and hold while dragging the mouse to choose a rectangular area.
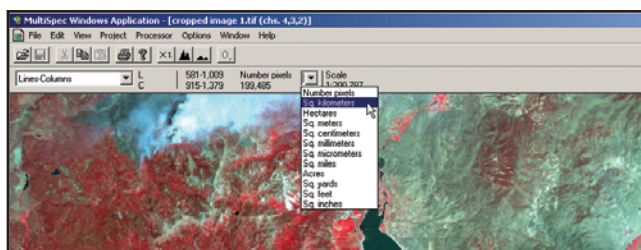   c. Next to "Number pixels" is a drop-down menu. Use this to select "Sq. kilometers" or another unit.

d. MultiSpec now displays how many square kilometers (or other unit) make up the area you selected.
8. How to save.
    a. In the file menu, select "Save Image to GeoTIFF As…"
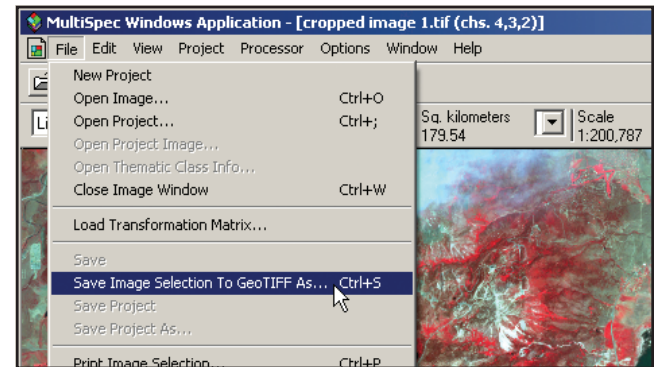
b. The "Save Active Image Window As:" window appears.
c. The filename has the band combination added. Click Save.


4. Experiment with the Reno image

Use the MultiSpec instructions and the suggested band combinations to answer the following questions about the forest fire near Reno, NV.

Students could write responses, or these questions could be used for class discussion.
• Look again at the table with the commonly used band combinations for Landsat 7. Which band combination shows most clearly the size of the area burned by the fire? (7,4,2; 4,3,2; and 5,4,3 work well; however, 7,5,4 shows the burn area better.)
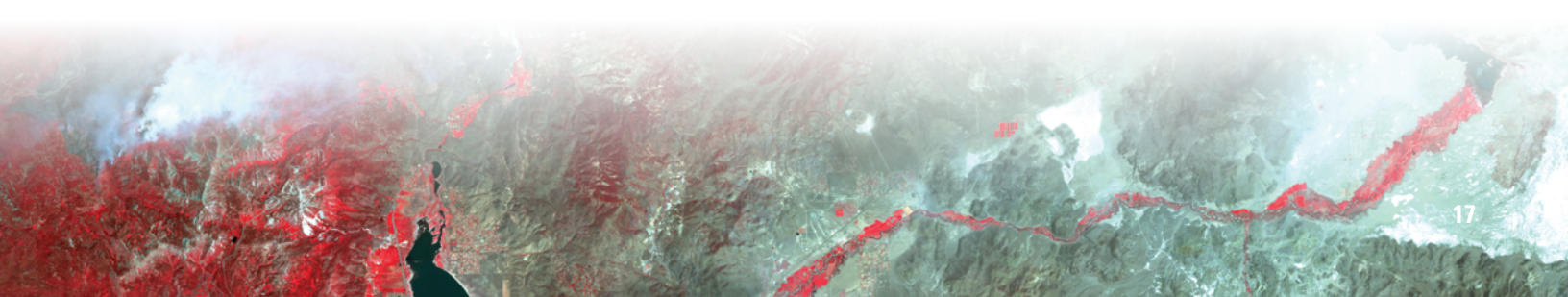
- Which commonly used band combination shows most clearly the extent of smoke? (3,2,1—the band combination that is closest to natural color shows well the extent of the smoke and how it obscures Reno. The combination 4,3,2 shows the residential areas a little better, although it does not show the smoke as well.)
- Of the following band combinations, which one allows you to filter through the smoke and observe land surface features? 7,5,3; 5,4,3; 7,4,1; 6,5,5; 4,2,1 (6,5,5 is best. Using band 5 in both the green and blue wavelengths makes it possible to filter through the smoke. 7,5,3 also filters through enough smoke to show the urban areas slightly more clearly than 6,5,5.)
- Of the following band combinations, which one shows where the fires were burning at the time of the image? 4,2,1; 6,5,5; 7,5,3; 6,3,6; 5,3,2 (6,5,5 uses the thermal band to reveal the fires as the bright spots, and 7,5,3 will work well too. And 5,3,2 shows both smoke and fire.)
- Of the following band combinations, which ones best show the urban area in this image? 3,2,1; 5,4,1; 7,5,3 (3,2,1 and 5,4,1 are band combinations used for urban area studies, but in this image, smoke obscures Reno. 7,5,3 can be used here to see the extent of Reno's urban areas.)
- Which commonly used band combination best shows agriculture and vegetation? (4,3,2 is a common band combination to use for vegetation studies—healthy vegetation appears red.)
- Imagine you are a remote sensing specialist living and working in Reno, and you are studying satellite images of this fire. Because the images show a lot of smoke, you want to send out warnings to residents about air quality. What direction is the smoke blowing at the time of this image? How can you tell? Which, if any, residential areas need to be warned? (The smoke is blowing generally east and north from the fire location, directly over the Reno urban area. Likely, a citywide message should go out about possible poor air quality, especially for people who have respiratory problems.)
- Challenge: Estimate the area, in square kilometers, that has been burned by the forest fire in this image. (See Step 7 in the previous section.) (A very rough estimate, based on a rectangular area centered on the burn area, is 45 to 50 square kilometers.)

Resources

Biehl, Larry, 2015, MultiSpec: Purdue Research Foundation, accessed November 20, 2015, at *https://engineering.purdue.edu/~biehl/MultiSpec/*.

National Aeronautics and Space Administration, 2001, High resolution views of fire near Reno: Earth Observatory Image of the Day, accessed November 20, 2015, at *http://earthobservatory.nasa.gov/IOTD/view.php?id=1530*.

National Aeronautics and Space Administration Goddard Space Flight Center, 2010, How are satellite images different from photographs?: accessed November 20, 2015, at *http://compositor.gsfc.nasa.gov/*.

U.S. Geological Survey, 2012, Landsat—A Global Land-Imaging Mission: U.S. Geological Survey Fact Sheet 2012–3072, 4 p., accessed November 20, 2015, at *http://pubs.usgs.gov/fs/2012/3072/*.

U.S. Geological Survey Earth Resources Observation and Science (EROS) Center, 2015, USGS EROS home page at *http://eros.usgs.gov*.

Notes: